Air Drying Bacon Slices to Reduce a_w: An Anti-Clostridial Alternative to Sodium Nitrite

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ABSTRACT

Low temperature air drying studies were conducted on bacon slices to determine the practicality and effectiveness of this method for reducing water activity (a_w) as an anti-clostridial alternative to sodium nitrite. Isotherms were developed to determine the extent of moisture removal required to achieve a_w = 0.92 or lower; these levels have been found to inhibit *C. botulinum*. Drying to these levels of inhibition can be accomplished in approximately 1.75 hr. Drying rates are significantly affected by air temperature, air flow rate, and slice overlap. Experimental data indicate drying can be accomplished with no substantial change in product quality.

INTRODUCTION

THE PROPOSED REDUCTION or elimination of sodium nitrite as a curing component in processed meats has been the subject of considerable research over the last decade. During this time, attention has been focused on the study of bacon, where residual nitrite has shown a high degree of correlation with the formation of carcinogenic N-nitroso compounds (Pensabene et al., 1979, 1980). Nitrite has several well-known beneficial effects in meat curing, the most important of which is the role that sodium nitrite plays in retarding *Clostridium botulinum* growth and toxin production. In the United States and Canada, studies have shown that the risk of toxin production is minimal for both normal (120 - 150 ppm) and low (50 - 60 ppm) nitrite levels even when the bacon has undergone temperature abuse for 1 wk at 27°C (Hauschild and Helsheimer, 1980). Unfortunately, trace amounts of nitrosopyrrolidine were found even in low nitrite bacon (Sen et al., 1974). This fact, coupled with the potential for more severe temperature abuse, especially in underdeveloped countries, indicates the need for continued research for an alternative to sodium nitrite as an anti-botulinal agent. Sofos and Busta (1980) list a number of physical and chemical controls as potential alternatives to sodium nitrite. One such alternative, dehydration, is the subject of this paper.

The dehydration of meat has been practiced for centuries as a method of preservation. Removing water by drying concentrates the water-soluble nutrients and reduces the water activity (a_w) thereby inhibiting or preventing the outgrowth of spoilage and toxinogenic microorganisms. Processed bacon exhibits a water activity ranging from 0.97 to 0.99 and is thus liable to spoilage through the growth of a wide range of organisms. By reducing the water activity below 0.93, many of the organisms, and most importantly *C. botulinum*, can be inhibited (Ohye and Christian, 1967; Riemann, 1973; Tompkin and Christiansen, 1976).

Various attempts have been made at lowering the water activity of bacon by drying. Hennergardt (1975) has reported on a method of freeze-drying bacon slices. These freeze-dried slices were stored in vacuum packages for 6 months at 38°C with no reported adverse effects. For most applications, however, the freeze-drying process is economically prohibitive. A number of researchers have employed a precook or prefrying step to accomplish the same purpose. Mattson (1978) demonstrated that precooking could be used to lower the bacon a_w to 0.85. It has also been established that a combination of microwave and hot air or steam reduced the a_w of bacon to acceptable levels for *C. botulinum* inhibition (Anon., 1977). A large amount of fat rendering is, however, inherent to the precooking operation, leaving a product that although acceptable for hotel/restaurant applications, is not generally salable to individual consumers.

In order to minimize the amount of fat rendering as well as investigate a more economical method of drying bacon, low temperature, low humidity air drying techniques were studied. This paper presents the results of that study.

MATERIALS & METHODS

THE BACON used in this study was purchased locally as fully processed slabs. Specific formulations for the curing step were unknown, but composition included sodium chloride, sucrose, sodium ascorbate, sodium nitrite (≤100 ppm), sodium tripolyphosphate, and hydrolyzed plant protein. The bacon was cooked in the smokehouse for 9 hr yielding a product that was approximately 99.5% of green weight. The bacon was sliced to the desired thickness (±0.01 cm) at this laboratory using a Berkel Model 180 GS high speed slicer. Slice order was carefully maintained allowing for the selection of specific slices for certain analytical evaluations (i.e., fat analysis, water activity measurement, and moisture analysis). By using alternate slices for drying, the fat content of each dried slice was estimated by a fat analysis of the two surrounding slices. Because of the high losses of fat encountered when preparation by grinding was used, the fat analysis was done on bacon cut into 3-cm squares. These pieces were soaked in petroleum ether for 18 hr and then extracted for 5 hr using Soxhlet extraction.

A number of bacon slabs were used for the drying experiments. Replicate experiments were conducted on adjacent or near adjacent slices from the same belly. Drying of all individual bacon slices, including pieces for the separate fat and lean study, was accomplished in a cylindrical, Plexiglas laboratory scale dryer, with a diameter of 2 inches. Type T thermocouples were placed inside the dryer to measure surface and dry bulb temperature. A rotameter was used to measure the air flow rate. Air velocities over the slices in this system ranged from 15 - 50 cm/sec. The air humidity was controlled by bubbling the drying air through specific concentrations of sulfuric acid to achieve a desired humidity of 10 - 50%. The individual bacon slices were hung vertically to minimize surface contact and heating due to conduction. Moisture loss (measured as weight loss) was determined every 30 min. Drying curves were constructed based on these measurements. Duplicate data are shown for all drying curves. These duplicate experimental data were compared by analysis of their representative regression equations using the method described by Neter and Wasserman (1974). Experimental data were then pooled and a composite regression curve is presented.

Water activities were measured using a Kaymont "Rotronic Hygroskop (Model DT)." The system was calibrated using saturated salt solutions of known relative humidity (Greenspan, 1977). The accuracy of the system was determined to be ±0.015 a_w units. A water jacket on the sample holder fed by a constant temperature bath maintained the desired temperatures (±0.1°C) for all water activity measurements.

Multiple, shingled slices were dried in a forced circulation air dryer (Sinnamon et al., 1968). In this dryer, dehumidification was accomplished using a desiccant column packed with 4 mesh $CaSO_4$. An American Meter "Diacon" dew-point apparatus was used to monitor and control downstream humidity by proportioning the amount of air passed through the desiccant column and the air which bypassed desiccation. The air rate was measured with a Meriam Instrument Model 50 MCZ-4P laminar flow element connected to an inclined manometer. Air velocities ranging from 50 - 180 cm/sec were used for these experiments. Drying curves were constructed in the same manner used for the individual slices. All slices were analyzed for moisture content by the standard vacuum oven method (AOAC, 1970).

A sensory evaluation, using 16 trained taste panelists, was conducted to establish differences in the bacon slices due to drying. Slices from a given bacon slab were separated sequentially into groups of eight. Within each group, four slices were identified for analysis in the undried state (fat, peroxide, and two taste samples). The remaining four slices were air dried and prepared for analysis (fat, moisture, peroxide, and taste). Samples were maintained in refrigerated storage until time of analysis. The bacon slices were fried at 175°C in a preheated electric pan. Frying time for the undried bacon was 6 min (3 min each side) and for the dried bacon slices was 4 min (2 min each side). After frying the bacon was drained to remove excess grease. The extent of rancid off-flavor development was assessed with a scoring system based on a six-point scale (1 = very strong; 6 = none). Acceptability of the bacon samples was determined with a nine-point hedonic scale (1 = dislike extremely; 9 = like extremely) of Peryam and Pilgrim (1957). Taste scores were evaluated using an analysis of variance and Duncan's multiple range test (Duncan, 1955). Samples were panelled at 1-wk intervals over a 3-wk span. Peroxide determinations were made using AOAC Method 28.023 (AOAC, 1980).

RESULTS & DISCUSSION

Moisture sorption isotherms

Konstance et al. (1983) showed that the type of drying had an impact on the desorption isotherms of bacon slices at 25°C and constant fat level. In Fig. 1, the isotherms for air and freeze-dried bacon slices are shown. Freeze-dried slices exhibited higher water activities at a given moisture content. This may be due to changes in the water-holding capacity created by the freezing process (Lawrie, 1966).

These differences indicate that sorption data for freeze-dried bacon slices will not adequately describe the requirements for an air drying system. In developing the moisture desorption data for air-dried bacon, two parameters, bacon composition and storage temperature, were considered.

Variations in bacon composition, especially in terms of fat:lean ratio, are large. The effects of this variability on the desorption isotherm and in turn the amount of drying required to assure a "safe" water activity level of 0.92 was of primary concern. In Fig. 1, for example, the desorption isotherms (25°C) are shown for air-dried bacon slices at 10%, 50%, and 70% fat. At constant water activity, the quantity of water sorbed increased with decreasing fat content.

The desorption isotherms for air-dried bacon slices, stored at temperatures ranging from 5 - 40°C were, for all practical purposes, identical at $a_w > 0.85$. These findings agree with the data of Konstance et al. (1983) for freeze-dried slices. In Fig. 2 moisture reduction is plotted against water activity. The data represent 25 separate experiments from three bacon bellies with essentially the same cure composition. In each experiment a bacon slice of known fat content was dried for a specific period of time to a desired level of water activity. The fat contents investigated were 40%, 50% and 60%. Moisture reduction was calculated from the initial weight, final weight, and moisture content of each dried bacon slice. The accuracy of the water activity measurements was ±0.015 a_w units. Although a fat-independent relationship was observed, a knowledge of the initial moisture content of the bacon was necessary for a_w prediction. A moisture reduction of approximately 50% was required to achieve $a_w = 0.92$.

Single-sliced drying

Drying rate curves of the major components of bacon, fat and lean, were developed. Drying was accomplished in air under mild conditions. Bacon fat (Fig. 3), which has a low moisture content, exhibited a drying rate that is characteristic of internal diffusion control. Bacon lean (Fig. 4), on the other hand, underwent an initial falling rate period that appeared to be linear with moisture content (section AB, Fig. 4). This falling rate period has been described by Treybal (1968) as unsaturated surface drying. Constant rate drying was not observed in bacon fat or bacon lean.

Commercially produced bacon slices are typically 0.24 – 0.27-cm thick, with a fat content ranging from 45 - 65% and a moisture content ranging from 25 - 40% (wet basis). Fig. 5 shows a drying rate curve for a typical slice of bacon. As with bacon lean, a period of unsaturated surface drying occurred initially. This linear falling rate period continued until the moisture content was reduced to approximately 0.17g H_2O/g solids. The moisture content required to achieved inhibition levels of a_w (0.90 – 0.92), was approximately 0.25g H_2O/g solids. Dehydration of a typical bacon

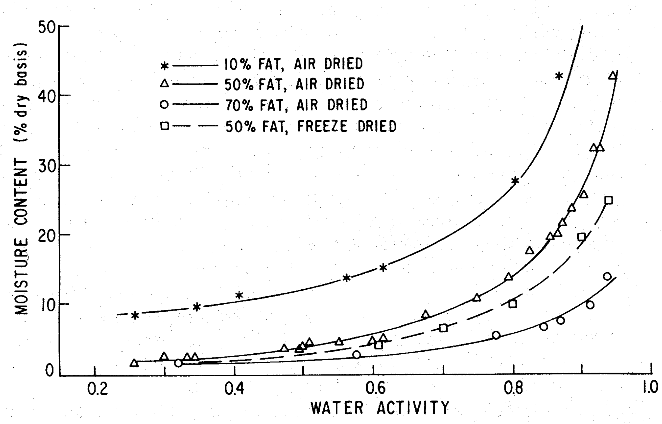

Fig. 1—Moisture desorption isotherms of bacon slices at 25°C. Effects of composition.

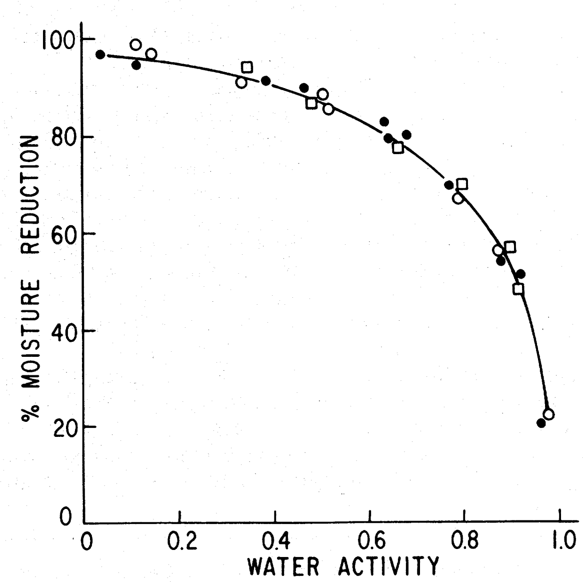

Fig. 2—Relationship of moisture reduction and a_w at various fat levels (○ - 40%, ● - 50%, and □ - 60%).

slice to achieve this a_w reduction would occur entirely in the region of unsaturated surface drying. The derivation of the equations describing the falling rate period were presented by Treybal (1968).

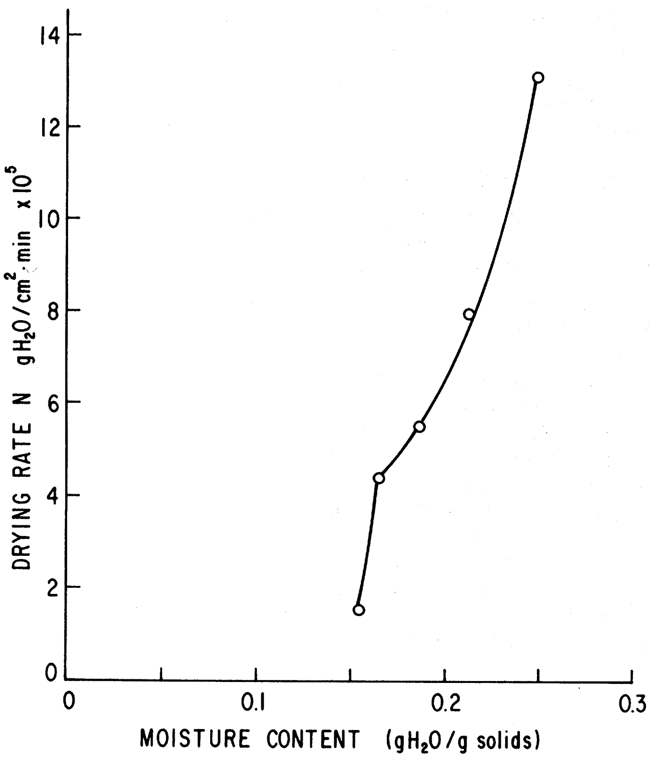

Fig. 3—Rate of drying bacon fat (25°C, 10% RH, 36 cm/sec).

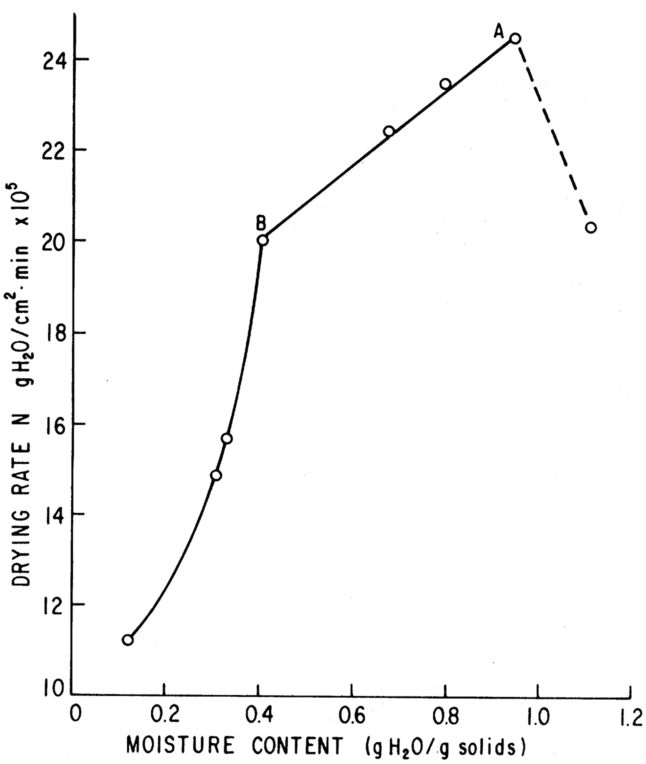

Fig. 4—Rate of drying bacon lean (25°C, 10% RH, 36 cm/sec). Section A-B is the linear falling rate period.

Based on the assumption of unsaturated surface drying, the rate of drying during the falling rate period can be defined generally by Eq. (1):

$$N = \frac{-L_s dx}{A\, d\theta} \tag{1}$$

For any given set of drying conditions, the drying rate of a given bacon is only a function of moisture content and time. Rearranging to yield the drying time gives:

$$\int_0^\theta d\theta = \frac{L_s}{A} \int_X^{X_1} \frac{dX}{N} \tag{2}$$

where: θ = drying time (min); A = drying surface area (cm^2); X_1 = initial moisture content (g H_2O/g solids); X = moisture content at time θ (g H_2O/g solids); N = drying rate (g H_2O/(min · cm^2); L_s = weight of dry solids (g).

As derived by Treybal (1968), in the special case where N is linear in x, as occurs during unsaturated surface drying, and when N_m is the logarithmic average of the rate N at moisture X, and N_1 at moisture X_1, then Eq. (2) can be written as:

$$\theta = \frac{L_s (X_1 - X)}{AN_m} \tag{3}$$

Noting that $L_s = \rho_s Z_s A$, where ρ_s = apparent bacon density (g solids/cm^3) and Z_s = slice thickness (cm), and expressing Eq. (3) in terms of a moisture ratio yields

$$\frac{X}{X_1} = 1 - \frac{N_m \theta}{\rho_s Z_s X_1} \tag{4}$$

The mechanism of evaporation during the falling rate period is the same in a constant rate period. The effects of such variables as slice thickness, air velocity, temperature, and relative humidity are thought to be the same as for constant rate drying (Treybal, 1968). In order to establish the validity of the assumption of a linear falling rate period for the data presented in this study, the effect of these variables on drying rate was investigated.

Effect of slice thickness

Drying data were obtained for bacon slices at four thick-

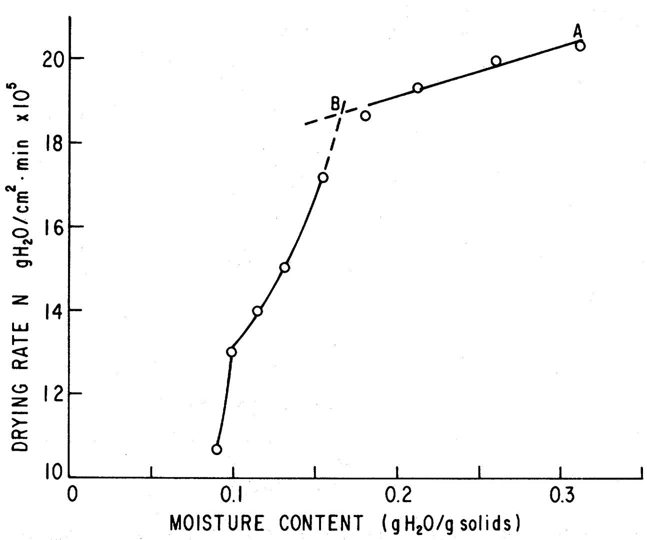

Fig. 5—Rate of drying whole bacon slice (25°C, 10% RH, 36 cm/sec, 0.24 cm thickness). Section A-B is the linear falling rate period.

nesses (0.16, 0.24, 0.32, and 0.48 cm). As before, these slices were air dried at a temperature of 25°C, a relative humidity of 10%, and an air velocity of 36 cm/sec. The drying curves (Fig. 6) appear to be linear in the first 120–150 min of drying. The slopes of these linear portions, calculated using regression analysis, were 4.91×10^{-3}, 3.28×10^{-3}, 2.19×10^{-3}, and 1.68×10^{-3} at thickness of 0.16 cm, 0.24 cm, 0.32 cm, and 0,48 cm, respectively. In unsaturated surface drying, the slopes of these lines should be proportional to $1/Z_s$. Comparison of the slopes shows good agreement to this expected proportionality.

The drying curves were predicted from Eq. (4), using the log mean average of the drying rates determined from Fig. 5 ($N_m = 1.98 \times 10^{-4}$ g $H_2O/(cm^2 \cdot min)$) and an apparent density of $0.6 g/cm^3$ as determined by volume weight measurements. The predicted curves showed excellent agreement with the experimental data through 120 min of drying. These results support the hypothesis that the mechanism of bacon drying to anticlostridial water activity levels is unsaturated surface drying. Deviation from predictions after 120 min may be attributable to the end of unsaturated surface drying.

Effects of air velocity

Fig. 7 illustrates the course of drying of bacon slices, 0.16-cm thick, that were air dried at 25°C and three different air velocities (18, 36, and 46 cm/sec). The calculated values of N_m increased from 0.84×10^{-4} to 2.43×10^{-4} g/(cm^2 – min) as the air velocity was increased from 18 to 46 cm/sec at 10% RH. For most foods dried with the air flow parallel to the drying surface, the drying rate during constant rate drying, N_c, was proportional to the mass velocity, G, g/($cm^2 \cdot$ sec) (Van Arsdel and Copley, 1963) as shown in Eq. (5):

$$N_c = d\ G^{0.8} \tag{5}$$

where d is a constant. This empirical relationship was essentially confirmed in this study by correlation of initial drying rates (calculated from initial slopes of the drying rate curves in Fig. 7) to G via a power law expression with an exponent of 0.72.

The drying data shown in Fig. 7 support the assumption of unsaturated surface drying through the first 120 min of drying for the hither air velocities (36 and 46 cm/sec). At an air velocity of 18 cm/sec, this model of drying was not followed for the entire period required to reach an a_w of 0.92.

Effect of temperature and humidity

The effects of drying temperature (20°C, 25°C, 29°C, 35°C) for bacon slices, 0.32-cm thick, dried at a relative humidity of 10%, an air velocity of 36 cm/sec were examined. For unsaturated surface drying, the drying rate (N), was proportional to the difference between the air temperature (T_q) and the surface temperature of the bacon (T_s). These temperature differences varied by less than 10% for slices dried at temperatures less than 35°C, and the rate of drying in this small temperature range was essentially identical. During drying at these temperatures surface temperature remained below 30°C and no melting of fat was apparent. When the dry bulb temperature was increased to 35°C, the slices exhibited a coating of melted fat over most of the bacon surface area. Surface temperature increased to 32°C and a reduction in the drying rate was noted. Drying temperature should, therefore, be controlled at 29 – 30°C to prevent melting of fat while obtaining the best drying rate.

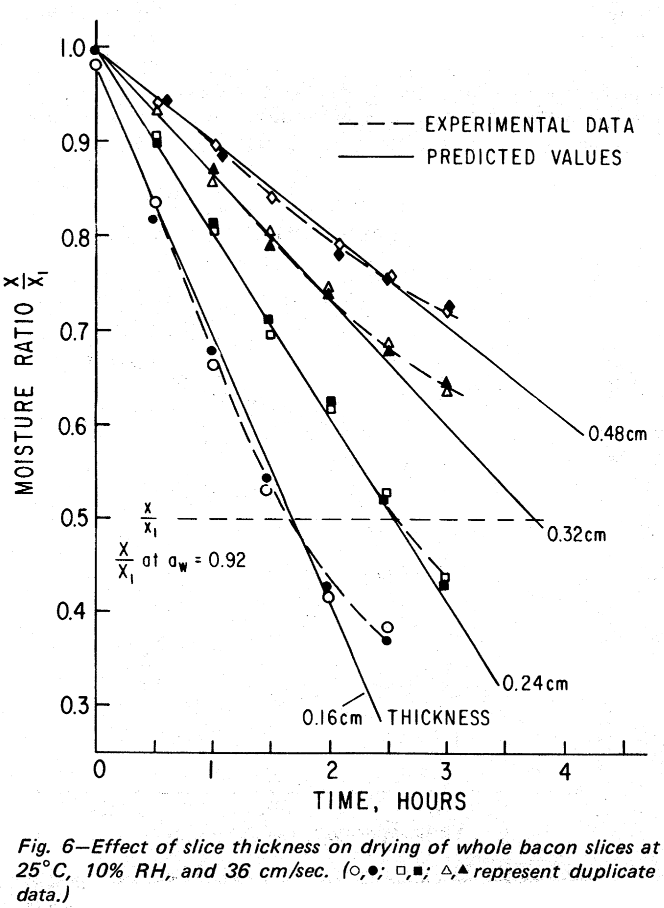

Fig. 6—Effect of slice thickness on drying of whole bacon slices at 25°C, 10% RH, and 36 cm/sec. (○,●; □,■; △,▲ represent duplicate data.)

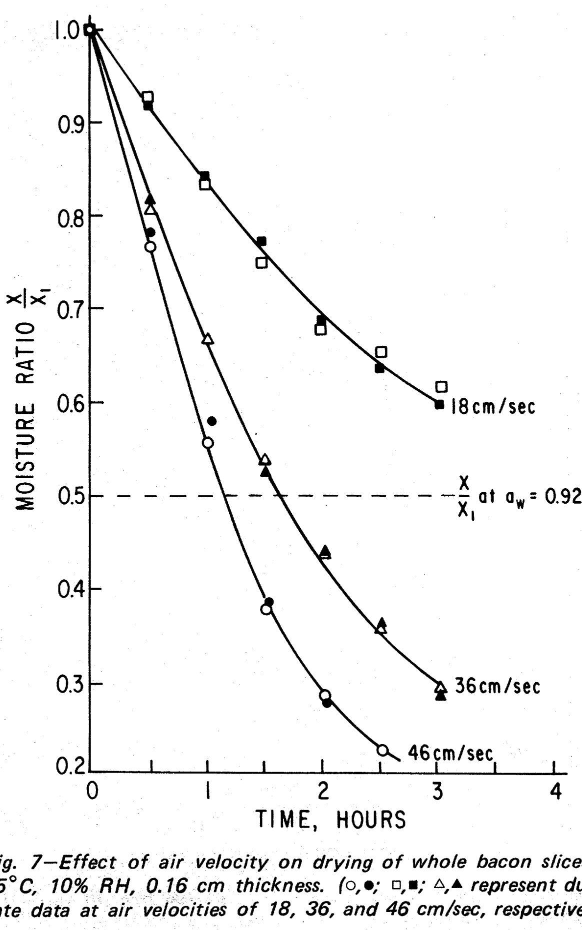

Fig. 7—Effect of air velocity on drying of whole bacon slices at 25°C, 10% RH, 0.16 cm thickness. (○,●; □,■; △,▲ represent duplicate data at air velocities of 18, 36, and 46 cm/sec, respectively.)

Humidity effects on the drying curves for bacon slices 0.24-cm thick dried at 25°C and 36 cm/sec are shown in Fig. 8. Reduction in drying rate accompanied the increase in humidity. Drying rates from Fig. 8 in the unsaturated surface drying period were 10% RH – 1.98×10^{-4} g/cm^2 • min; 50% RH – 1.02×10^{-4} g/cm^2 • min; 85% RH – 0.55×10^{-4} g/cm^2 • min. At higher relative humidities total drying time would extend beyond the unsaturated surface drying region and significantly longer drying time would be required.

As can be seen from the data, individual bacon slices from the bacons studied generally followed an unsaturated surface drying regime when typical commercial bacon slices were used. Deviation from linearity was experienced with thicker slices and at the lowest air velocity. In these cases, the unsaturated surface drying did not extend to the required level of water activity.

Table 1—Analysis of drying data using the Yates algorithm[e]

Source of variation	Observed variable	Estimated effects
a	0.00180	0.0135
b	0.00289	0.0121
ab	0.00446	0.0059
c	0.00189	0.0053
ac	0.00321	0.0010
bc	0.00262	0.0028
d	0.00222	0.0058
ad	0.00340	0.0008
bd	0.00229	0.0030
cd	0.00250	0.0015
⩾ third order	—	<0.0012

[a] Shingling factor
[b] Air velocity
[c] Air temperature
[d] Air humidity
[e] Box et al. (1978)

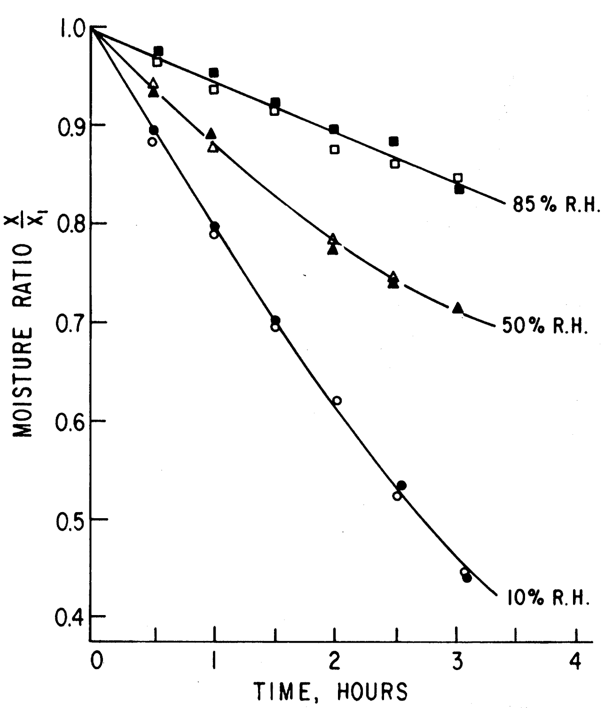

Fig. 8—Effect of humidity on drying of whole bacon slices at 25°C, 36 cm/sec, 0.24 cm thickness. (○,●; □,■; △,▲ represent duplicate data.)

Shrinkage

Shrinkage was the most evident change in product characteristics that occurred during air drying of bacon slices. During drying at 25°C, 36 cm/sec, and 10% RH, for typical bacon slices where no fat losses occurred, weight reduction was due solely to moisture removal. Shrinkage was caused primarily by the self-contraction of the material as moisture was removed. The volume of the material is often a linear function of the mean moisture content during shrinkage (Keey, 1972), as expressed in Eq. (6):

$$V_f = V_o\ (1 + Cx) \qquad (6)$$

where: V_f = product volume at final moisture (cm^3) V_o = moisture free volume (cm^3); C = bulk shrinkage coefficient; x = moisture content, dry basis, g H_2O/g dry bacon. Bacon shrinkage was evaluated in terms of surface area because (a) no measurable change in slice thickness occurred during drying, and (b) slice thickness was small, relative to surface area. Shrinkage was evaluated using a surface area analog of Eq. (6).

$$A_f = A_o\ (1 + gx) \qquad (7)$$

where A_f = product area at final moisture (cm^2); A_o = surface area at zero moisture (cm^2); g = area shrinkage coefficient; and x = moisture content, dry basis, g H_2O/g dry bacon.

In Fig. 9 A_f/A is plotted against moisture. Here, A is the surface area of a raw bacon slice (40 cm^2). The bacon was dried at 25°C with the drying air at 10% RH and an air velocity of 36 cm/sec.

Regression analysis results inthe linear relationship:

$$A_f/A = a + bx \qquad (8)$$

(a = 0.668, b = 0.667, and r, the correlation coefficient = 0.965). The intercept a, in this case, is equal to A_o/A giving the following relationship:

$$A_f = A_o\ (1 + \frac{b}{a} x) \qquad (9)$$

and

$$A_f = 26.53\ (1 + 0.998\ x) \qquad (10)$$

Slices from the bacon studies, dried to an a_w = 0.92 (corresponding to moisture content of 29%), would shrink approximately 13% during drying.

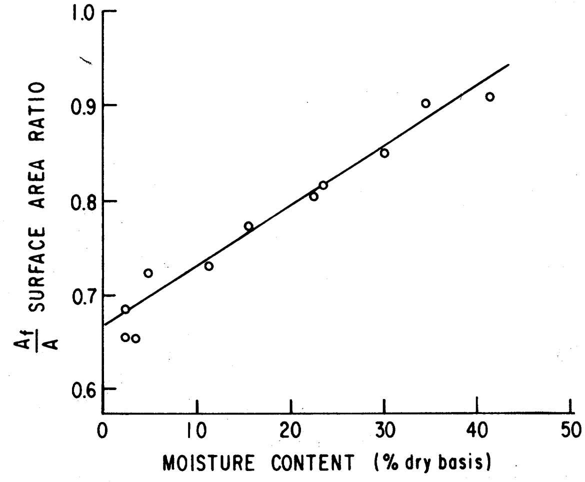

Fig. 9—Shrinkage of whole bacon slice. (Air dried at 25°C, 10% RH, 36 cm/sec, 0.24 cm.)

Packaged bacon drying

Since continuous drying of individual bacon slices presents serious packaging and handling problems from a processing standpoint, studies were conducted on air drying bacon with the slices overlapped (shingled). The data obtained from the single-slice studies were used as the basis for determining the range of the parameters investigated in the shingled experiments. A 2^4 experimental design, incorporating the following parameters, was used to determine drying rate response: S_f = shingling factor (%) – 50, 75; V = air velocity (cm/sec) – 180, 50; T = air temperature (°C) – 25, 18; and RH = air humidity (%) – 10, 50. Shingling factor represents the amount of product overlap: i.e., at a shingling factor $S_f = 75$, 25% of the product surface was exposed. Using the Yates algorithm (Box et al., 1978) the effects of these parameters on the slope of the drying cuve $N/\rho_s Z_s X_1$ were analyzed (Table 1). The variance was estimated by assuming that the three and four-factor interaction effects reflect contribution to experimental error alone. Calculation of the pooled estimate of the variance (s_R^2) was made utilizing the sum of squares (ss) from these higher order interactions. Locating the mean of the reference distribution at zero and comparing the estimated effects showed that: shingling facator (a), air velocity (b), the two-factor interaction of shingling and air velocity (a, b), and humidity (d), significantly affected the slope of the drying curves. The effects of these parameters are shown in Fig. 10 (shingling factor and air velocity) and Fig. 11 (temperature and humidity). Utilizing a 50% shingling factor 24 slices of bacon (average thickness 0.26 cm) can be dried to a water activity of 0.92 in approximately 100 min using 10% RH, 25°C, and an air velocity of 180 cm/sec.

Product quality

The uniformity of drying of the bacon slices when shingled at 75% was poor. A large variation in the moisture content, when individual slices in a package were compared, approached 30%. When a 50% shingle was used, uniformity was excellent. With the exception of end effects, where slices were 5 - 10% drier, variation of the water activity across a package of 24 slices was insignificant ($\sigma^2 = 7 \times 10^{-5}$ at a mean $a_w = 0.904$). The water activity of each end slice was about 6% lower ($a_w = 0.850$). The decrease in uniformity due to the end effects would be minimized in a continuous operation.

The taste panel was unable to detect any significant differences (P = 0.95) in rancidity between the dried and undried samples (Table 2). All samples were characterized as "very faint rancidity" (score = 5). Tasters rated all of the samples in the "like moderately" range in the hedonic test (Table 3). Differences in the scores of the hedonic test were not statistically significant (P = 0.95). Although sodium nitrite is not a strong antioxidant (relative to most phenolic antioxidants) the low concentrations of this compound in the bacon samples may in part have contributed to the delay of oxidation.

Table 2—Sensory evaluation for rancidity development[a]

Time	0 wk	1 wk	2 wk	3 wk
Sample				
Undried	4.93	5.07	5.31	5.09
Dried	4.64	5.47	5.31	5.27

[a] 1 = very strong; 6 = none.

Table 3—Overall sensory evaluation (Hedonic evaluation)[a]

Time	0 wk	1 wk	2 wk	3 wk
Sample				
Undried	7.07	7.27	7.38	7.00
Dried	7.00	7.33	7.23	6.91

[a] Hedonic scores: 1 = dislike extremely; 9 = like extremely.

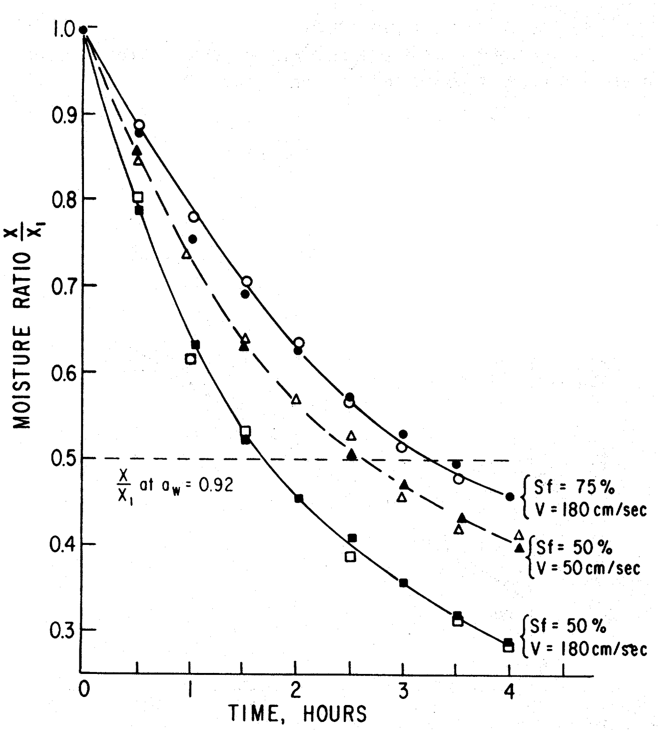

Fig. 10—Effect of air velocity (v) and shingling factor (S_f) on drying of shingled bacon, 24 slices at 25°C, 10% RH, 0.26 cm thickness. (○, ●; □,■; △,▲ represent duplicate data.)

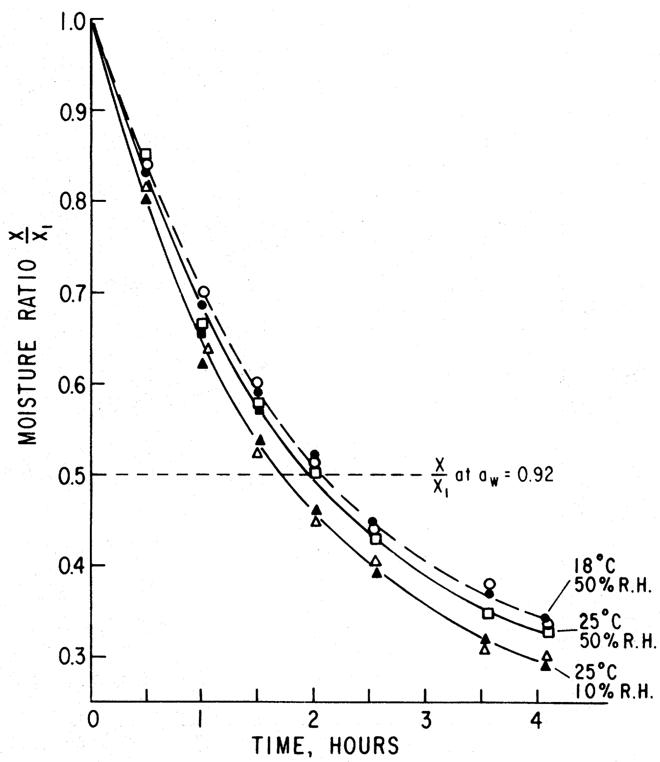

Fig. 11—Effect of temperature and humidity on drying of shingled bacon, 24 slices at 50% shringling, 180 cm/sec, 0.26 cm thickness. (○,●; □,■; △,▲ represent duplicate data.)

Peroxide values were determined during storage as a means of monitoring fat oxidation. In all cases the peroxide values were less than 1.0 meq/1000g fat. A duplicate experiment to measure peroxide development in the dried bacon samples showed the same low peroxide levels during the 3-wk storage period. These low peroxide levels indicate that autoxidation occurs in the early phases of the induction period and supported the findings of the taste panel.

CONCLUSIONS

THE MOISTURE SORPTION relationships for dried bacon slices were dependent upon the drying method. Within an air-dried system the most significant change in the sorption relationship occurred with differences in the fat/lean ratio. Using a fat-independent relationship where percent moisture reduction was compared to water activity, it was found that removing 50% of the water in bacon lowered water activity levels to 0.92, which is adequate in inhibiting growth and toxin production by *C. botulinum.*

Drying of individual bacon slices within the limits of the drying schemes studied generally followed an unsaturated surface drying regime. The drying rate of typical bacon slices was a linear function of moisture content throughout the period of interest ($a_w \geqslant 0.92$). During this period, the drying rate of these bacon slices exhibited a typical response to parameters such as air velocity, humidity, and slice thickness. Deviation from this linearity was experienced as slice thickness increased and at very low air velocities. In the narrow range of temperatures studied, little differences in the drying rate was noted as temperature was increased. When the drying temperature reached 35°C however, the drying rate decreased as fat began to melt. When shingled slices were dried, the drying rate decreased. Drying at a 50% shingling factor, 25°C, and 180 cm/sec air velocity reduced the water activity of bacon slices (0.26-cm thick) to 0.92 in approximately 1.75 hr with no melting of fat and no discernable adverse effect on product quality. The slices shrank linearly in this first 2 hr of drying to approximately 85% of the original size. Taste tests for rancidity and overall flavor, as well as peroxide determinations, indicate that bacon slices dried in air were not different from their undried counterparts. Air drying of bacon can be considered a possible anticlostridial alternative.

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